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Competitive Effects of Bluebunch Wheatgrass, Crested Wheatgrass, and Cheatgrass on Antelope Bitterbrush Seedling Emergence and Survival

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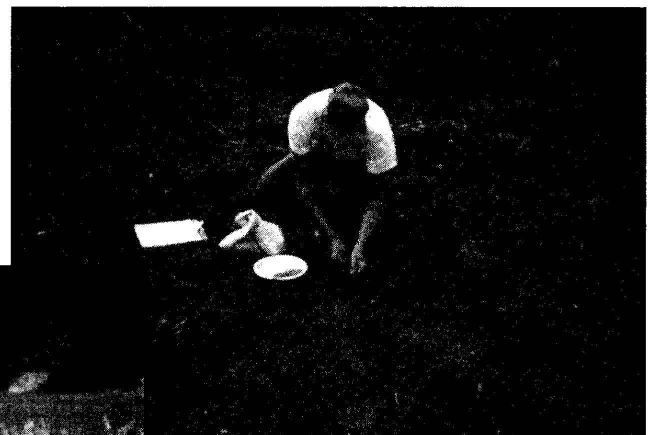

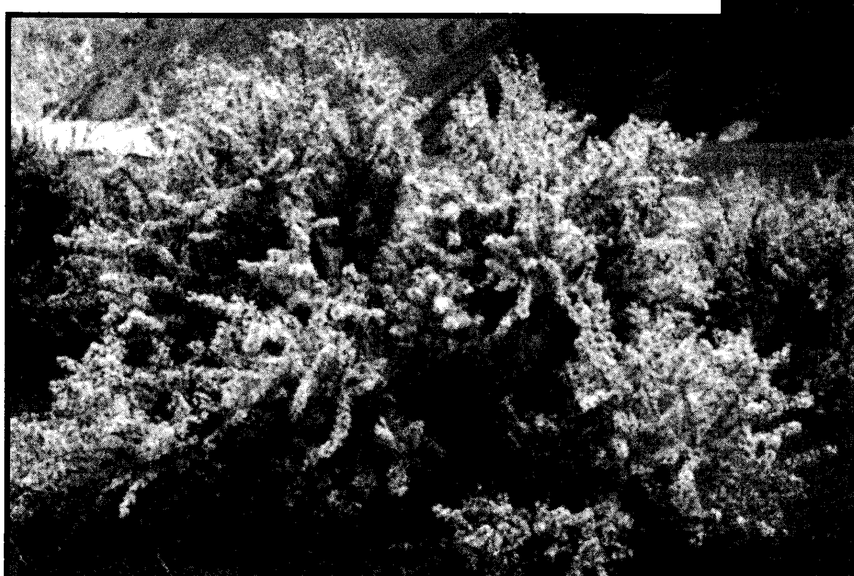

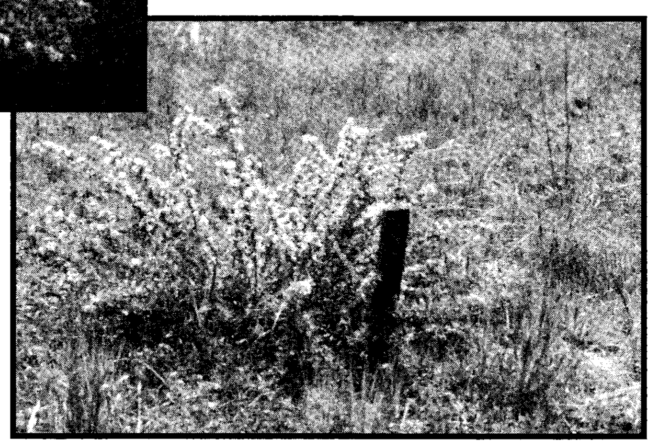

Abstract

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The competitive environment into which plant seedlings emerge often determines the survival and performance of these individuals. This study was designed to determine the effects of bluebunch wheatgrass (*Pseudoroegneria spicata*), crested wheatgrass (*Agropyron cristatum*), and cheatgrass (*Bromus tectorum*) on soil moisture depletion, associated antelope bitterbrush (*Purshia tridentata*) seedling emergence, xylem pressure potential, and subsequent survival. In the fall of 1992, antelope bitterbrush seed was sown into the following four established competitive matrices: (1) bluebunch wheatgrass, (2) crested wheatgrass, (3) cheatgrass, and (4) bare soil control plots. Soil moisture and bitterbrush seedling xylem pressure potential data were collected through the spring and summer of 1993. Antelope bitterbrush seedling survival data were collected through the spring and summer of 1993, and again in July 1994. Invasion of bur buttercup (*Ranunculus testiculatus*) in the spring of 1993 increased the competitive environments with densities of 470 plants per m^2 in the crested wheatgrass, 760 in bluebunch wheatgrass, 920 in control and 1,060 in cheatgrass plots. Soil moisture in crested wheatgrass plots tended to be lower than soil moisture in the bluebunch wheatgrass plots. The number of emerged bitterbrush seedlings were significantly ($r^2 = 0.99$) negatively correlated with the number of total annuals per m^2. Antelope bitterbrush seedling xylem pressure potentials were less negative in the bluebunch wheatgrass plots compared with the other plots. Percent antelope bitterbrush seedling survival over 2 years was significantly higher (nearly twice) when grown in association with bluebunch wheatgrass than seedlings grown in association with crested wheatgrass, cheatgrass, or bur buttercup.

Keywords: *Pseudoroegneria spicata, Agropyron cristatum, Bromus tectorum, Purshia tridentata, Rununculus testiculatus,* xylem pressure potential, soil moisture, rangeland restoration

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Introduction

Shrubs dominate many plant communities throughout the Western United States, particularly in the Great Basin. McGinnies (1972) suggested that the northern desert shrub type is among the most important shrub community in North America. Shantz and Zon (1924) recognized three main associations in the sagebrush or northern desert shrub type. Among these is the big sagebrush (*Artemisia tridentata* Nutt.) association including communities dominated by big sagebrush, rubber rabbitbrush (*Chrysothamnus nauseosus* Britt.), and antelope bitterbrush (*Purshia tridentata* Pursh.), among others.

These communities, consisting of a variety of small to large shrubs that form an open canopy, support a grass/forb understory. Shrub-dominated communities provide crucial winter and spring habitat for wild ungulates, particularly mule deer and elk, as well as cattle and sheep (McKell and Goodin 1973; Plummer 1972). High energy content of dry grass culms coupled with high protein levels found in the current year twig growth of shrubs provide excellent winter and spring forage (Cook 1972).

Relatively constant and heavy use by wild and domestic ungulates has created changes in species composition of both woody and herbaceous components of many communities. Cheatgrass (*Bromus tectorum* Linn.) and other annual weeds have invaded and dominate many areas within brush communities where native plant species have been weakened (Vallentine 1989). Crested wheatgrass (*Agropyron cristatum* Linn.) has been seeded onto millions of acres of rangeland throughout the Western United States to stabilize herbage production, protect watersheds, and control weeds (Holechek 1981). Crested wheatgrass persists under heavy grazing pressure relative to many native counterparts and has been seeded into weakened native plant communities.

These introduced annual and perennial grass species appear to affect native shrub recruitment and subsequent community composition. Several studies have shown that competition from introduced grasses restricts either shrub seedling emergence or establishment or both. Hormay (1943a,b) reported that cheatgrass retarded natural establishment of antelope bitterbrush. Holmgren (1956) concluded that few antelope bitterbrush seedlings were able to survive the first summer in cheatgrass stands. Monsen and Shaw (1983) suggested that established stands of desert wheatgrass (*Agropyron desertorum* Linn.), a close relative of crested wheatgrass, limited the natural regeneration of antelope bitterbrush. Price and Brotherson (1987) partially attributed low recruitment rates in stands of Stansbury cliffrose (*Cowania mexicana stansburiana* Torr.) to competition from annual grasses. Melgoza and others (1990) determined that cheatgrass competes with needle-and-thread grass (*Stipa comata* Trin. & Rupr.) and Douglas rabbitbrush (*Chrysothamnus viscidiflorus* Nutt.) for soil water and negatively affects their water status and productivity. Eissenstat and Caldwell (1988) reported that sagebrush indicator plants had lower survival, growth, reproduction, and late-season water potential in areas dominated by desert wheatgrass in contrast to areas dominated by bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh.] Love).

Native grass understories may also negatively impact shrub seedling survival (Eissenstat and Caldwell 1988; Hubbard 1959). However, introduced annual and perennial grasses, namely, desert wheatgrass, crested wheatgrass, and cheatgrass utilize soil moisture earlier in the growing season than the native bluebunch wheatgrass because of their rooting characteristics (Aguirre and Johnson 1991; Caldwell and Richards 1986; Harris 1967; Harris 1977; Harris and Wilson 1970). The ability of these introduced grasses to utilize soil moisture earlier in the growing season than bluebunch wheatgrass gives them a competitive advantage over bluebunch wheatgrass and quite possibly, over other native species as well. Although bluebunch wheatgrass competes with shrub seedlings, it may not have as detrimental effect on shrub seedling survival as the introduced species (Eissenstat and Caldwell 1988). Few studies have focused on the influence of competitive herbs on shrub seed germination and emergence, but it seems apparent that there is an effect on seedling recruitment.

This study was designed to determine the effect of various understory species, namely, cheatgrass, 'Hycrest' crested wheatgrass, and 'Goldar' bluebunch wheatgrass on (1) soil moisture depletion in the top 114 cm of the soil profile, (2) the xylem pressure potential of antelope bitterbrush seedlings, and (3) the emergence and subsequent survival of antelope bitterbrush seedlings. The hypothesis tested was that shrub seedling emergence and subsequent survival are lower in areas dominated by the introduced grass species (cheatgrass and crested wheatgrass) than bluebunch wheatgrass.

Materials and Methods

Study Area

The study area is located 4.5 km south of Nephi, UT, at an elevation of 1,385 m. Soil at the site is classified as a Nephi silt loam. This soil is a fine-silty, mixed, mesic Calcic Argixeroll with a soil pH of approximately 8.3. Average annual precipitation is 356 to 406 mm, mean annual air temperature is 7 to 11 °C, and the average frost-free season is 100 to 140 days. The study site originally supported a mixed shrub and bunch grass community consisting of basin big sagebrush *Artemisia tridentata* Nutt. sp. *tridentata*, antelope bitterbrush, rubber rabbitbrush, and blue bunch wheatgrass. The site has been used to conduct dryland cropping and community restoration research for over 50 years.

Competitive Matrices

Twenty-four competitive matrix plots, consisting of eight replicate plots of each of the three grass species (Goldar bluebunch wheatgrass, Hycrest crested wheatgrass, and cheatgrass), and four bare ground control plots were established. The two wheatgrass species were greenhouse propagated and transplanted to the study site in the fall of 1991. At the time of transplanting, plants were approximately 6 months old. Goldar bluebunch wheatgrass is a cultivar native to the Palouse prairie of northern Idaho. Hycrest is a cultivar of crested wheatgrass and is commonly seeded on western rangelands. Transplants were placed at 0.5 m spacings in 9 m^2 matrices with 49 plants in each matrix. The transplants were watered periodically through the first growing season to ensure the establishment of a uniform and strong competitive matrix. Cheatgrass seed was collected near the study site and seeded in rows spaced 20 cm apart in the fall of 1992.

During the summer of 1992, a rodent-proof fence was erected around the site to keep rodents from eating the shrub seeds. The site was also weeded several times during the summer in an attempt to reduce the confounding effects of weeds in the experiment.

In the fall of 1992, four 25 seed caches (74 percent viability) of antelope bitterbrush were sown into each of four 0.25 m interspaces (yielding 400 seeds per matrix) in the interior of each competitive matrix and each control plot. In addition, aluminum tubes were implanted to a depth of about 114 cm in the outer row of half of the competitive matrices to provide access for a neutron probe for soil moisture measurements.

Soil moisture, xylem pressure potential, and densities of antelope bitterbrush seedlings were measured and recorded at seven dates through the spring and summer of 1993: April 29, May 13, May 20, May 27, June 4, June 25, and August 2. In addition, bitterbrush seedling densities were recorded again in July 1994 to determine percent survival. Soil moisture was measured gravimetrically in the top 22 cm and with a neutron probe (California Pacific Nuclear Model 503DR) in the lower profile (22 to 114 cm). Soil moisture was reported as percent by volume.

Predawn xylem pressure potentials were measured with a Scholander type pressure bomb (Waring and Cleary 1967). At each sampling date, one shrub seedling was harvested and measured from each matrix to determine xylem pressure potential. Additionally, the youngest fully expanded leaf of three randomly selected tillers of the competing species in each matrix were used to determine the xylem pressure potential of the competitors. At each sampling date seedlings were counted in each interspace (numbers of living and dead seedlings were recorded separately and dead seedlings were then removed).

In late May, one-half of all the competitive matrices for each species were defoliated by removal of 80 percent of the foliage to simulate heavy spring use by ungulates. A height/weight relationship procedure was used to determine the defoliation height for various utilization levels. Biomass was also measured by weighing the clipped material and then determining its dry weight. Bur buttercup (*Ranunculus testiculatus* Crantz), other weedy species, and cheatgrass densities were measured along with height and basal circumference of wheatgrass species to quantify the competitive matrices.

The two-factor factorial design (four levels of competitive matrices by two levels of matrix defoliation) was analyzed using the Number Cruncher Statistical System (NCSS) general linear models procedure to determine the response differences in antelope bitterbrush emergence and survival as well as soil moisture and xylem pressure potential differences between treatments (NCSS 1989). Mean separations were conducted using a protected Fisher's Least Significant Differences procedure at the p-values indicated for each parameter (all $P < 0.10$).

Results and Discussion

Competitive Matrices

When data were collected in the spring of 1993, the average bunchgrass was approximately 50 cm in circumference and cheatgrass densities averaged 914 plants per m^2 in the cheatgrass plots. Biomass in the grass plots was regressed against percent survival at the date of defoliation (May 20). There was no significant relationship between these two variables.

Although the site was weeded several times the previous summer, bur buttercup seed persisted in the soil and germinated the following spring. Bur buttercup densities averaged 1,060 plants per m^2 in cheatgrass, 920 in control, 760 in bluebunch wheatgrass, and 470 plants in crested wheatgrass matrices. The high bur buttercup densities in the cheatgrass plots, combined with the cheatgrass, formed an annual competitive matrix rather than a simple cheatgrass competitive matrix. Control plots also had high bur buttercup densities which likely influenced soil moisture, antelope bitterbrush seedling xylem potential, and antelope bitterbrush seedling survival. Bur buttercup densities were significantly higher in bluebunch wheatgrass matrices than in crested wheatgrass matrices, suggesting that crested wheatgrass is a stronger competitor than bluebunch wheatgrass.

Soil Moisture

Results from the soil moisture analysis showed that defoliation had no significant effect on soil moisture or subsequent xylem pressure potential readings of associated antelope bitterbrush seedlings. This was unexpected, but may be explained by the unusually high frequency and intensity of rainfall experienced throughout the spring and early summer of 1993.

The two-way interaction for soil moisture between date and depth was significant (fig. 1). This indicates

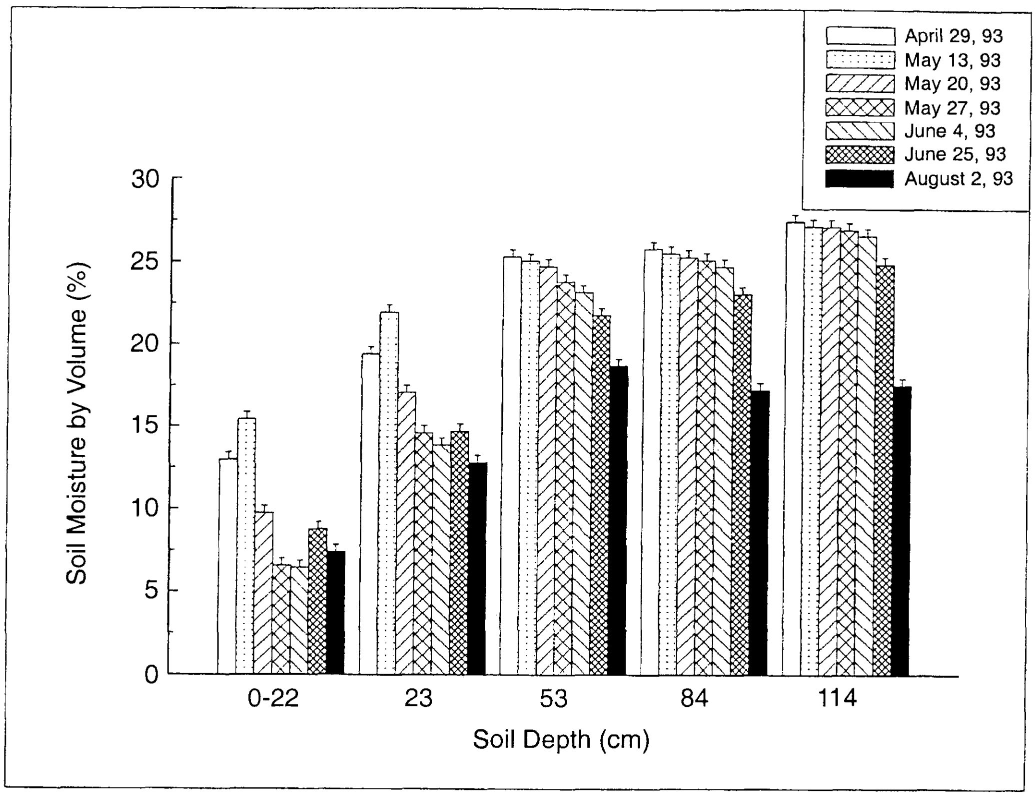

Figure 1—Percent soil moisture by volume at five depths through the spring and summer of 1993 (interaction, p < 0.01).

that soil moisture in the upper portions of the soil profile was depleted more rapidly, and fluctuated significantly in response to pulses of precipitation. Cline and others (1977) also determined that water loss was especially rapid in surface soil layers and less rapid deep in the soil profile. Soil moisture in the upper part of the soil profile is critical to establishing shrub seedlings, particularly early in the growing season. The soil profile exhibited an expected, yet somewhat retarded depletion curve for moisture through the summer. The competitive matrix by soil depth interaction for soil moisture was also significant (fig. 2). Soil moisture in the crested wheatgrass matrices was consistently lower than in the bluebunch wheatgrass or cheatgrass matrices in the top 84 cm. This is consistent with our hypothesis as well as the findings of Eissenstat and Caldwell (1988). They reported that desert wheatgrass depleted more moisture from the soil profile than did bluebunch wheatgrass. Soil moisture in the bluebunch wheatgrass and cheatgrass plots did not significantly differ from each other averaged across season, although soil moisture values were consistently higher in bluebunch wheatgrass matrices in the upper 53 cm of the soil profile. Below 53 cm, soil moisture was slightly higher in cheatgrass matrices than in bluebunch wheatgrass matrices. This is consistent with the findings of Cline and others (1977) who concluded that soil water stored below 50 cm in a cheatgrass community was not fully exploited. The more favorable than expected soil moisture profile for cheatgrass may be explained in part by higher than normal precipitation in May and June. This may have allowed soil moisture in the cheatgrass plots to remain relatively high. A repeat of this experiment during a dry spring would be needed to adequately test the relationship of water use patterns between cheatgrass, bluebunch wheatgrass and crested wheatgrass.

Antelope Bitterbrush Seedling Emergence

In the spring of 1993 there was no significant difference between an average of 156 antelope bitterbrush seedlings emerged in the crested wheatgrass

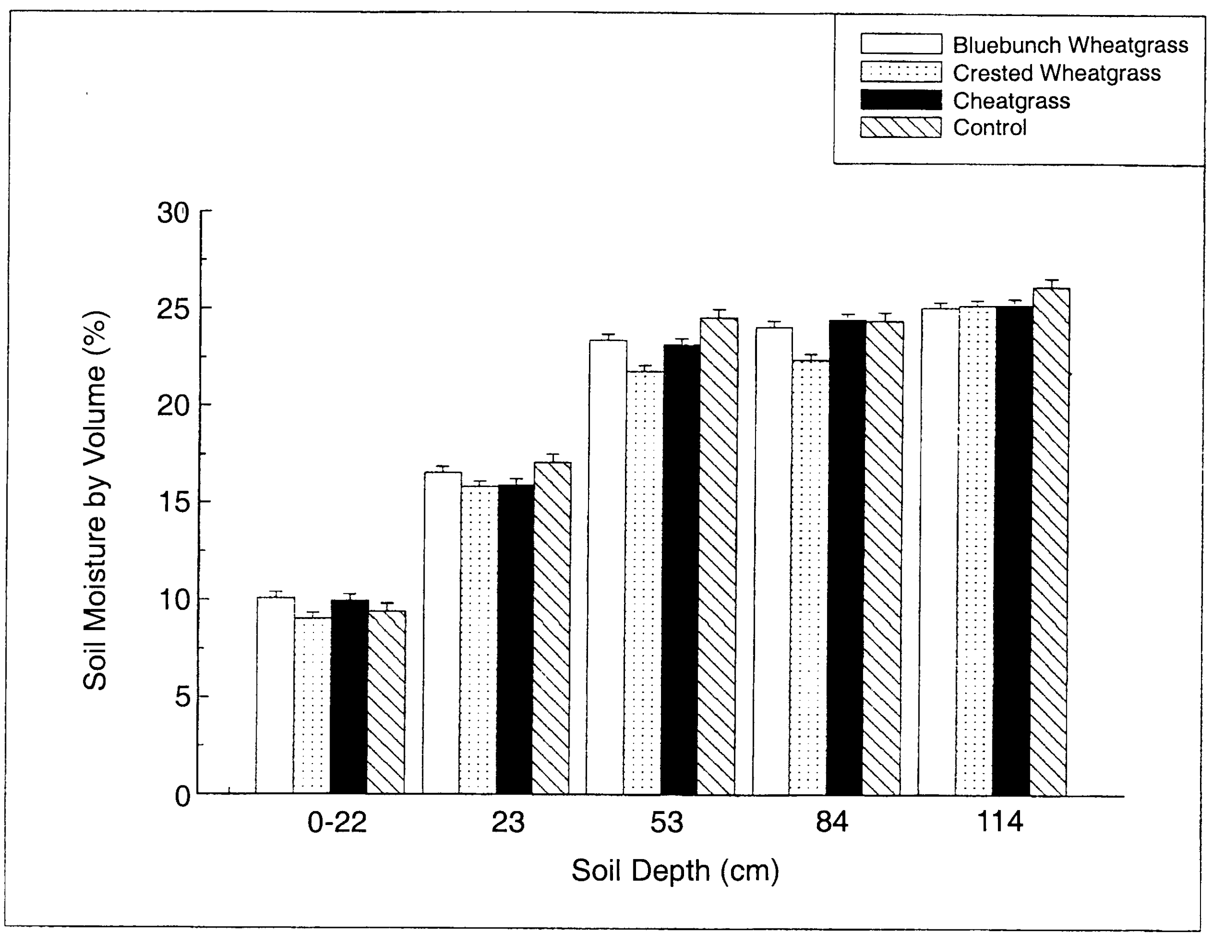

Figure 2—Percent soil moisture at five depths in the four different competitive matrices (interaction, $p < 0.01$).

matrices, and the 148 in bluebunch wheatgrass or 134 in control matrices. There were significantly ($p = 0.08$) fewer emerged seedlings (93) in the cheatgrass matrices than either the crested wheatgrass or bluebunch wheatgrass matrices. When seedling numbers were regressed against total annual plant density (cheatgrass + annual forbs), a significant negative relationship ($r^2 = 0.99$) was revealed. As annual plant density increased, the number of bitterbrush seedlings decreased.

Grass and Bitterbrush Seedling Xylem Potentials

Xylem pressure potentials of bluebunch wheatgrass did not significantly differ from crested wheatgrass, although an observed trend showed that bluebunch wheatgrass had less negative potentials than crested wheatgrass. This suggests that perhaps bluebunch wheatgrass is more efficient at using or conserving water than is crested wheatgrass, since bluebunch wheatgrass used less soil moisture yet had lower negative xylem pressure potentials than did crested wheatgrass. Bluebunch wheatgrass xylem pressure potentials tended to be less negative than cheatgrass potentials.

The two-way interaction between competitive matrix and collection date was significant for antelope bitterbrush xylem pressure potentials (fig. 3). Shrub seedlings in the bluebunch wheatgrass matrices had less negative xylem pressure potentials than seedlings in the other plots. Seedlings in crested wheatgrass plots exhibited the most negative pressure potentials late in the season as soil moisture declined. Eissenstat and Caldwell (1988), obtained similar results using desert wheatgrass with Wyoming big sagebrush transplants as indicator plants. They found that "*Artemisia* indicator plants had lower survival, growth, reproduction, and late-season water potential in the neighborhoods dominated by *Agropyron desertorum*, than in those dominated by *Agropyron spicatum* (bluebunch wheatgrass)."

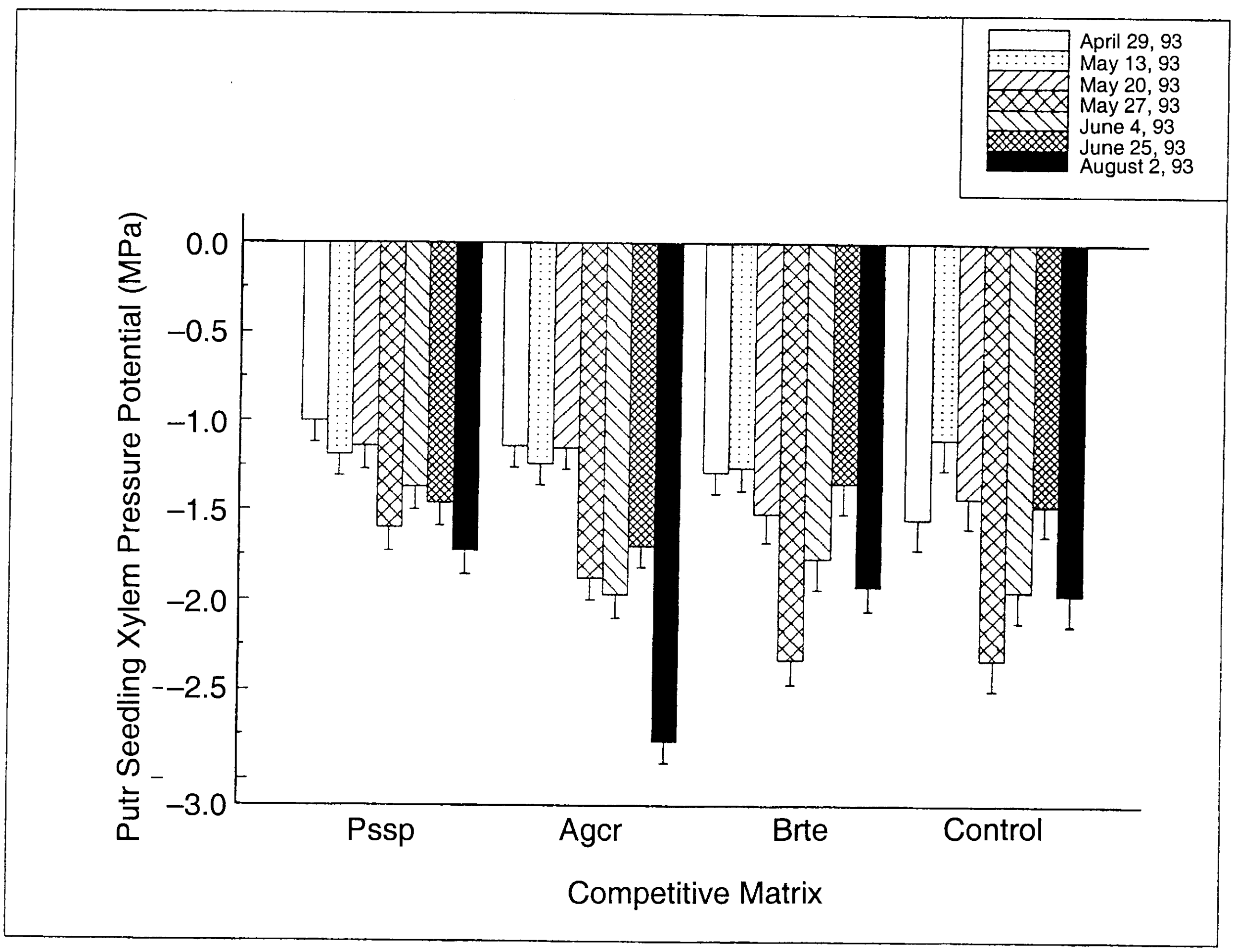

Figure 3—Antelope Bitterbrush seedling xylem pressure potentials in the four different competitive matrices through the spring and summer of 1993 (interaction, $p < 0.01$).

Antelope Bitterbrush Seedling Survival

Antelope bitterbrush seedling survival was not significantly different between matrix defoliation treatments. Again, higher than normal rainfall in May and June may not have allowed the soil to dry out sufficiently to show effects from the defoliation treatment, or the treatment was carried out too late in the season, so as not to affect the survival of bitterbrush seedlings.

Significant differences ($p = 0.03$) were detected among competitive matrices for percent antelope bitterbrush seedling survival at the end of the first summer. Percent antelope bitterbrush seedling survival averaged 19.7 in bluebunch wheatgrass, 11.9 in crested wheatgrass, 9.1 in control, and 6.6 in cheatgrass matrices. No significant difference between percent seedling survival in bluebunch and crested matrices was exhibited, although that trend is evident. Percent antelope bitterbrush seedling survival was significantly higher in bluebunch matrices than in the cheatgrass and control matrices. The analysis also showed a trend for higher seedling survival in crested matrices than in the cheatgrass and control matrices. One reason for lower survival in the cheatgrass and control matrices, versus the wheatgrass matrices, may be the tendency for bur buttercup densities to be higher in the control and cheatgrass matrices. Bur buttercup has been shown to be a strong competitor that negatively affects establishing plants (Buchanan and others 1978; Davis and Harper 1990). In addition, bitterbrush seedlings did not have any substantial thermal or protective cover in the relatively open control and cheatgrass matrices compared to the two wheatgrass matrices.

Antelope bitterbrush seedling survival exhibited a steady decline over time (fig. 4). At the conclusion of the study, July 1994, an overall decline in percent antelope bitterbrush seedling survival from the previous year was noted. However, the order and relative

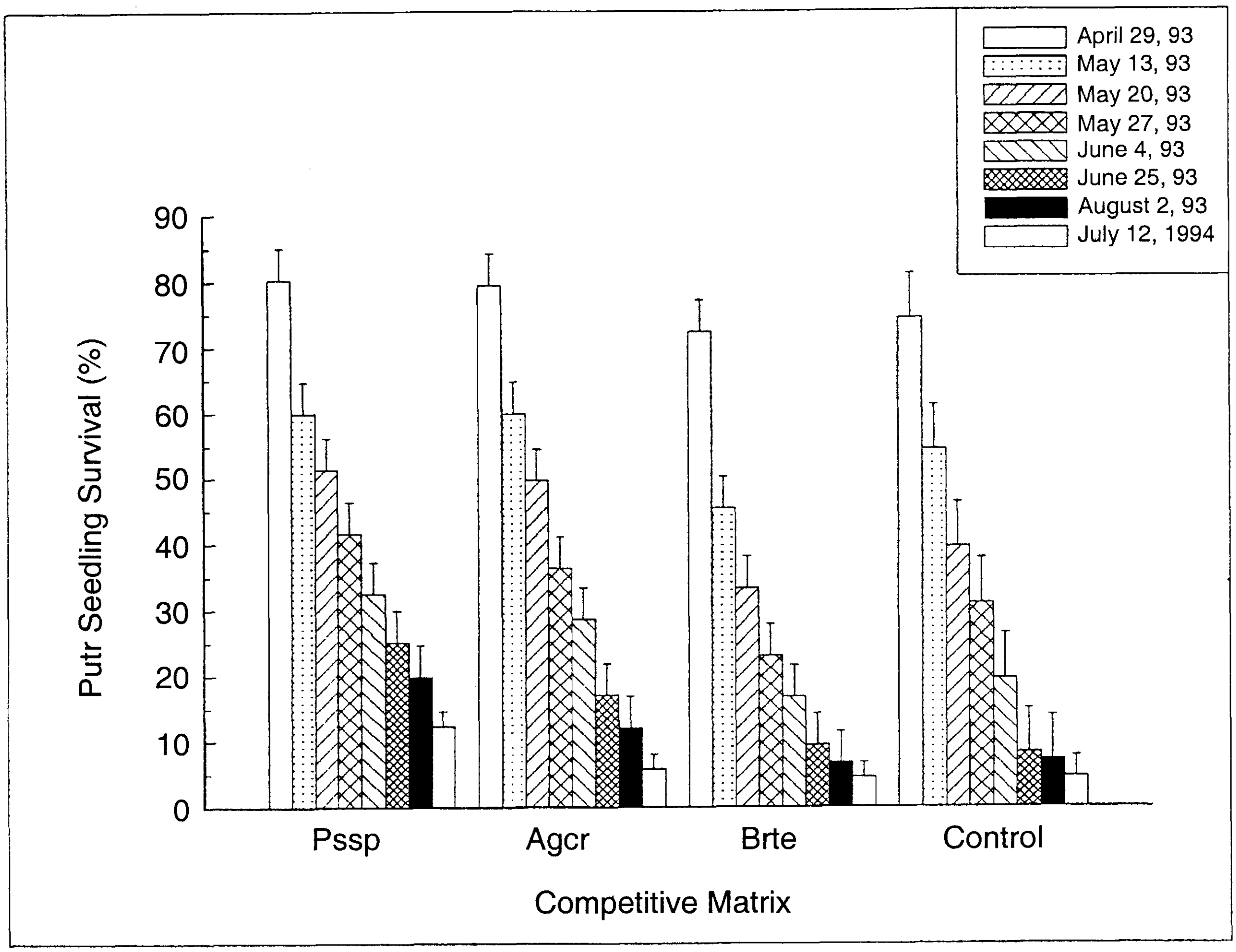

Figure 4—Percent antelope bitterbrush seedling survival in the four different competitive matrices from germination in 1993 to mid-summer 1994 (interaction, $p = 0.01$).

magnitude was unchanged from the end of the previous year. Second year survival of antelope bitterbrush seedlings was significantly higher in the bluebunch wheatgrass matrices than any other (p = 0.08).

Conclusions

Results from this study support the hypothesis that introduced species such as crested wheatgrass and cheatgrass, as well as bur buttercup, lower the survival of antelope bitterbrush seedlings relative to the native bluebunch wheatgrass. This negative effect can be attributed, at least in part, to the ability of these introduced species, especially crested wheatgrass, to extract more soil moisture than bluebunch wheatgrass. Even in a year where the natural precipitation pattern exceeded the normals in both the number of events and magnitude, the fact that bitterbrush seedlings in bluebunch wheatgrass matrices had less negative xylem pressure potentials than seedlings in the other competitive matrices further supports the hypothesis that crested wheatgrass, cheatgrass, and bur buttercup exploit soil moisture to a greater extent than the native bluebunch wheatgrass.

Bluebunch wheatgrass has co-evolved with various shrubs, including antelope bitterbrush. Thus, it is reasonable to assume that these species are able to coexist. When the temporal physiological activity balance within native communities is disrupted with the introduction of cheatgrass and crested wheatgrass, the seedlings of many native shrub species may be unable to successfully compete for the limited moisture and nutrients. If shrub recruitment is inhibited, existing shrub stands will eventually become decadent and slowly disappear.

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